Classical Engineering Education Coping with Engineering Profession Demands

M. M. Ciampi [1]
President of World Council on Systems Engineering and Information Technology
Secretary of IEEE Education Society
São Paulo, BRAZIL
E-mail: drciampi@copec.eu

C. R. Brito
President of IEEE Education Society
President of Science and Education Research Council - COPEC
São Paulo, BRAZIL
E-mail: drbrito@copec.eu

R. M. Vasconcelos
Board of Governors of IEEE Education Society
President of Pedagogical Council of the School of Engineering at University of Minho
Guimarães, PORTUGAL
E-mail: rosa@det.uminho.pt

L. A. Amaral
President of Computer Graphics Center - CCG
Professor of Information Systems Department at University of Minho
Guimarães, PORTUGAL
E-mail: amaral@dsi.uminho.pt

H. D. Santos
Vice President for Conferences of IEEE Education Society
Director of Information Systems Department at University of Minho
Guimarães, PORTUGAL
E-mail: hsantos@dsi.uminho.pt

V. A. Barros
Executive Secretary of Science and Education Research Council - COPEC
Researcher of Information Systems Department at University of Minho
Jataí, BRAZIL
E-mail: victor@copec.eu

[1] Melany M. Ciampi
M M Ciampi
drciampi@copec.eu

ABSTRACT

The present world scenario shows that without any doubt there is an increasing recognition that leadership in technological innovation is key to the nation's prosperity and security in a hypercompetitive, global, knowledge-driven economy. Universities must cope with this need and change to reach the levels of required quality education in order to form the professional who will leave university to the work market. The Engineering Education Team of COPEC – Science and Education Research Council has designed this program that is knowledge centered and specially challenging, which integrates classical engineering approaches and real experience in order to achieve a high level of engineers ready to perform as professionals or researchers. The goal is to form the Engineer – a professional that is capable to learn for life and be creative in many ways.

Conference Key Areas: Engineering Skills, Engineering Education Research.

Keywords: learning/teaching tools, best practices, work market, intellectual skills, knowledge-centered.

INTRODUCTION

In general sense, engineers can be defined as problem solvers, creators of ideas and concepts, builders of devices, structures, and systems. They apply their knowledge of science and technology to meet the needs of society, to solve its problems, and to pave the way for its future progress. The intellectual activities of engineering are heavily based on synthesis, design and innovation through the integration of knowledge. However, engineering is more than an intellectual discipline, like physics or chemistry. It is also a vocation characterized by great diversity.

The key to the ability of engineers to develop products, systems and services that are essential to public health, and the economic competitiveness of the nation's business and industry is the knowledge base created by engineering research. The new knowledge, generated through research, drives technological innovation, which is the transformation of knowledge into products, processes, and services, which, in turn, is critical to competitiveness, long-term productivity growth, and the generation of human wealth.

Another aspect is that the current standard engineering education appears neither to provide the full set of skills that engineers are likely to need in the future nor attract the right numbers or types of people to engineering.

Based on these facts the questions that arise are: How can education institutions provide students a strong and valuable knowledge? What key skills and competencies do today's engineers need?

The answer seems to be: if students are taught the skills of learning, then they will continue to learn on their own for the rest of their lives. How is this possible? By the well-

walked path of the tried and proven — the classical method of educating engineers. It means sufficient mastery of the basic tools of science and mathematics to address technological problems.

The way this can be achieved is by means of classical education, not as synonym of Christian education, but as an education with solid basis of knowledge in basic sciences and basic sciences of engineering. Students then will finish their course equipped with the right tools and a strong capacity of learning. Classical education then, in this sense, is a life-long process of applying the “tools of learning” - tools that are skills entailed in basic sciences, engineering basic sciences, and specific of engineering, which travels with the student through her/his career as professional or as an academic. In other words, the market seems to be ready for those who obtain a general engineering education and develop adaptable skills, which will serve them while their world continues to evolve [1].

Knowledge is a web, and so, there are no subjects that are unrelated to others. It happens the same with engineering training; the program is a web of knowledge, provided by studies, delivered in a time frame, interconnected and necessary to get the pertinent knowledge and development of skills that will enable them to learn by themselves. This is why students have to see the big picture from the beginning. It is important to show them, in the first week of classes, the whole program, as a big frame and its parts and the details of each part. It is a way to locate them within the program. It is hard, but not impossible and the effort is worth. The knowledge of the entire program has an effect in students who can see the value of solid knowledge in basic sciences as a start point for their formation and the importance of these as valuable tools.

Education is established in cultural economic, individual, philosophical, scientific and social advancement. In other words, education is the mean for developing the mind for the betterment of the individual and society. Advances in science and technology mean that the world will continue to change rapidly, so that the knowledge learned by students in specific careers will have a short lifespan. In contrast, those who achieve a general engineering education will develop adaptive skills, which will serve them while their world evolves. Since people tend to change jobs and occupational fields, several times throughout their lives, it is important to acquire a dynamic ability to absorb information, to adjust to organizational goals, and to navigate through complex work relationships; for this reason, a classical approach seems more useful for today’s work market.

The integrating part of the program comes from internships and practical projects, which are relevant for both: student’s studies and the real work scenario. The internship and the project offer opportunities to take the skills they are developing in the classroom to the real world. So, School provides internships in companies, in the field of student’s choice, during the fourth and filth years of college. They are then, at that time, more prepared to face these challenges [2].

The authors use "classical education" meaning knowledge centered education and refer to "classical method of educating engineers" as the same kind of approach. It refers to the choice of in class classes, with face to face interaction, strong and deep study, mainly in mathematics and physics, as the basis for the quality education that provide the tools that conception and application engineers need.

1. PROBLEM FORMULATION – NEW MARKET DEMANDS

The value of narrow specialization, at a time when engineering practice and engineering systems are becoming large and more complex, and involving components and processes from widely dispersed fields, is questionable. Many educators believe that the most important intellectual problems of our time will not be addressed through disciplinary specialization, but rather through approaches capable of integrating many different areas of knowledge.

This fact, added to competitiveness, made an engineering school, of a private University, decide to invest in a new civil engineering program, instead of opening a new program in another field, since this program is still the most sought course by young people in the region.

In order to overcome the difficulties of the hard competition and external evaluation of programs, the University has hired COPEC – Science and Education Research Team for Engineering Education, which has designed a program, which is knowledge centered and specially challenging. It is a program that integrates classical engineering approaches and real experience, in order to achieve a high level of engineers ready to perform as professionals or researchers. Their goal is to train Engineers able to learn for life and be creative in many ways.

The program has been specially designed, and aims to become the best one, in order to attract more students due to the competition in the region, that despite being a relatively small region, has five other universities offering the same program of civil engineering and faces also the external evaluation process by the Ministry of Education [3].

2. SETTING THE CONTEXT: TIMELESS EDUCATION

The classical/general education (and here as opposed to progressive education) is a type of education that has a history of over 2500 years in the West. It began in ancient Greece, was adopted widespread by the Romans, reduced after the fall of Rome, made a slow, but steady recovery during the Middle Ages, and was again brought to perfection in the Italian Renaissance. The main goal of classical education, in any level, is to form the whole person, in accordance with timeless intrinsic values; it is a very effective way to form free citizens, as opposed to controlled citizens.

The classic view of education states, essentially, that human beings are intelligent beings, which means that human beings want to know things, more specifically to know what things are and how they work. It is primarily focused on knowledge and not student-centered [4].

At University level, the classical/general education demands self-discipline and it produces intelligent curious young professionals, who can think, calculate, analyze, understand, solve problems and follow through on a wide range of perspectives. It is systematic and rigorous; it has goals and a method to reach the goals. It provides future professional the tools to learn and to adapt to the new work environment, as well as to the mutant work market of this millennium.

Looking at History, the classic engineering was responsible for the appearance of weapons, fortifications, roads, bridges, canals, tools, etc. In ancient times, in the eighteenth century, the first engineering schools emerged in France. They are: the École des Ponts et Chaussées (1747), the École de Mines (1783) and the École Polytechnique

(1794), it was the period when Science married Engineering. They all belong to the group of French Schools, that constitute mostly the so-called "generalist" Grandes Écoles, and the leading ones, of these groups, constitute the major part of the French scientific elite education system [5].

In the field of science research, what has been seen is that research work is not based on a top-down command-and-control hierarchy anymore. In this new virtual and complex system, scientists combine and recombine in research teams, based not on academic discipline or institutional affiliation or geographic location, but on the unique requirements of the problems they want to address. It means that researchers do not have to be in the same place of their collaborators, nor have they to be in the same place as the problems they seek to solve. There are international networks, which are more important to individual faculty members, than their departmental or institutional ties, since this network enlarges the possibilities of research and career success [6].

Besides this, the time is coming, when most people will have a number of jobs before middle age and when many jobs have not yet been developed; the question is: how can educational institutions form or train in a manner that may not yet exist? The classical/general education curriculum provides an answer.

3. THE APPROACH: THE CLASSICAL EDUCATION IN CIVIL ENGINEERING

It is estimated that today's college students will have over four jobs before the age of 30, and over ten jobs before they are 40. For core science, research, engineering and technology jobs specifically, around 78% of the net requirement between now and 2023 is made up of replacement demand, leaving 142,000 brand-new core science, research engineering and technology jobs being created. These new jobs are being created in a range of areas, with some sectors becoming much more science-focused over time. It means that there will be new opportunities and changing jobs is a very possible need [7].

In fact, many engineering graduates will work for small high-tech companies or consulting services companies, moving from organization to organization and role to role frequently. To adapt to this new work environment, engineering graduates must accept the personal responsibility for their lifelong learning through acquiring effective self-learning skills.

Perhaps, what is most missing in the current engineering education curriculum, crammed as it is increasingly with demanding technical material, is the opportunity for a truly liberal education, designed to enable young students to develop the deeper intellectual skills necessary to adapt to a world characterized by continuous change. So Classical Education can be a way to enable students for this new work market.

Classical/general education can be defined both: as a curriculum for broadening the mind—one of the hallmarks of an educated person—and as a way to prepare for active participation as a citizen. At present time, there is a sense that classical/general education should focus in the key attributes that employers value as needed by a generally educated person: critical thinking, writing, speaking, arguing, researching, and mathematical reasoning. In addition, to introduce a broad variety of subjects, classical/general education should exercise skills and habits of mind.

After the Second World War, with the cold war, and the run for the moon, education suffered a big change, added by the enlargement of students in University. These changes were necessary, however, due to the challenging and mutant educational

environment as well as the global market and the scientific and technologic new achievements it is rather difficult to figure out what kind of engineers training will be necessary. In order to face the new challenges, the classical engineering training is an approach that provides new engineers the right tools to perform and to learn for life [8].

There are two facts that have driven the engineering faculties: first, private universities are struggling to attract good students for their programs, once it guarantees the continuity of the colleges and programs and so the employees. Besides the external evaluation, that programs and colleges have been facing, push them to enhance the quality of the programs that they offer.

Because of these reasons, to attend the necessities of an engineering college of a private university, COPEC's team has chosen to propose the pursuit of a classical/general education approach for the civil engineering program and so form the "Engineer". The engineer who has knowledge and self-taught skills - a professional who can think, calculate, analyze, understand, solve problems and follow through a wide range of perspectives - social, economics and of sustainability among others. It is a way to attract good students to their programs, as it ensures the continuity of colleges and programs.

The proposed program is essentially, what says a famous and very appreciated Chinese Proverb – "Give a man a fish and you feed him for a day. Teach a man to fish and you feed him for a lifetime".

The specific civil engineering program started in 2014 and the enrollment was low, comparing with previous years. However, after three years the results have been very positive taking into account the trend of engineering programs, choices in young generation and the universities competitiveness for students in the region.

4. ENGINEERING EDUCATION – FACING GLOBAL MARKET

Civil engineers must serve in a competent, collaborative and ethical way, working as planners, designers, builders and promoters of the economy and construction as a factor of social promotion. In addition, they are managers of the natural environment and its resources, innovating and integrating ideas and technology in the public, private and academic sectors. They are the managers of risk and uncertainty caused by natural events, accidents and other threats; and also leaders in discussions and decisions that shape environmental policy and public infrastructure.

The proposal of a classic engineering program came as a response to develop a new educational approach with the goal of strengthening a civil engineering course that saw its enrollment declining each year.

The key elements are:

- have a well conceived, coherent, sequential curriculum;
- have all courses with strong and pertinent knowledge;
- adjust other parts of the education system of the program to support the goals of learning;
- provide teachers with a carefully conceived curriculum, filled with challenging texts and materials;
- provide students where they are going and how they are going to get there.

It is necessary to challenge students to acquire the knowledge that they really need to become engineers; a professional capable to do any work and overcome the unpredictable future when it is becoming difficult to anticipate the new professions and opportunities that will be needed [9].

The process is long, implies many changes, including teachers trained for the program and the achievement of the main objective, which is to foster in the students the analytical and verbal skills, creativity and innovation, entrepreneurship, the appreciation of complexity and ambiguity, and leadership, very important for the formation of the engineer of this millennium.

The curriculum has been set and discussed with a set of professors, specialists in their fields of expertise, and in accordance with the Law of the Ministry of Education, the organization that regulates and accredits University Schools Programs.

The curriculum is organized in order to provide students with basic sciences courses, taught during the first two years; followed by basic sciences courses of engineering deployed during the second and third years and the specific courses of engineering, in this case, civil engineering, with emphasis in concrete constructions and eco building construction (following the trend of sustainable buildings – energy efficiency and use of low emission of Co2 materials) [10].

The figure below shows a block of different courses that were added and that have been taught in a period that has been named as Pre – Program, which happens two weeks prior to the year schedule, when students have classes of Language usage, Instrumental English (usage of technical English), Mathematics (review of high school content) and Psychology (aspects of competitive and demanding pressure environment).

So the program design is as follows:

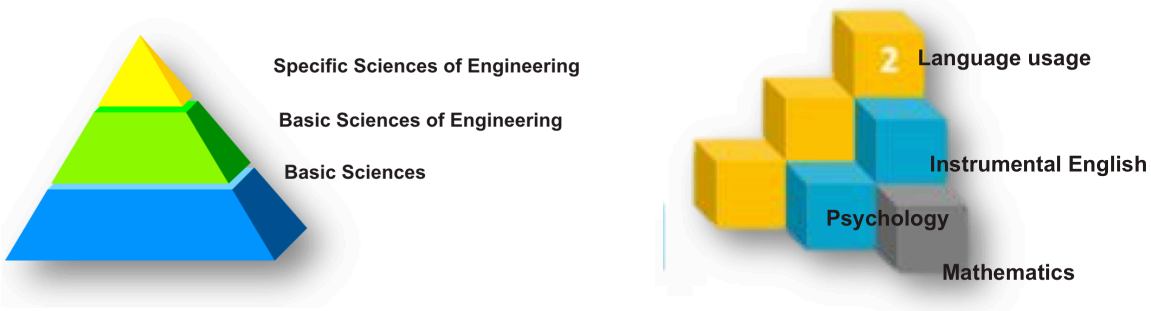

Fig. 1. Block of Different Courses that were added in a period that has been named as Pre-Program

5. THE CURRICULUM

Bellow, there is a chart of the basic cycle curriculum, that covers seven subjects in the first semester of the year of admission of the student in the Civil Engineering course and eight subjects in the second semester, totaling 27 credits in the first semester and 28 in the second semester. The content of subjects is taught deeply and with intense exercise sessions. It starts in the pre-program and lasts for all years.

Table 1. Basic Cycle Curriculum

	Discipline	CC	CW	TC	OC
1st	General Physics for Engineering I	4	0	4	

Semester	Experimental Physics for Engineering I	2	0	2	
	Introduction to Engineering Computing	4	0	4	
	Differential and Integral Calculus for Engineering I	4	0	4	
	Linear Algebra for Engineering I	4	0	4	
	Design for Engineering I	2	0	2	
	Introduction to Engineering	3	0	3	
	General Technological Chemistry	4	0	4	27
2nd Semester	General Physics for Engineering II	4	0	4	
	Experimental Physics for Engineering II	2	0	2	
	Numerical Calculus	4	0	4	
	Differential and Integral Calculus for Engineering II	4	0	4	
	Linear Algebra for Engineering II	4	0	4	
	Design for Engineering II	2	0	2	
	Mechanics I	4	0	4	
	Introduction to Materials Science for Engineering	4	0	4	28
CC – Credit class	**CW** – Credit work	**TC** – Total credits	**OC** – Overall credits		

6. FIRST RESULTS

2016 is the third year of this Civil Engineering program and the results are as follows.

Table 2. Civil Engineering Program

YEAR	Total of students that have entered in the Civil Engineering Program	Number of students of civil engineering that have opted for the Classical Engineering Program	% of enrollment rate
2014	180 students	89 students	49.44%
2015	180 students	100 students	55.56%
2016	180 students	136 students	75.56%

The table is based only on the enrollment number of students in the first and following years of program.

7. EXPECTED OUTCOMES

The initiative proposes specific learning outcomes and competencies such as:

- Applied learning: used by students to demonstrate what they can do with what they know;
- Intellectual skills: used by students to think critically and analytically about what they learn;
- Specialized knowledge: the knowledge students demonstrate about their individual fields of study;
- Broad knowledge: transcends the typical boundaries of students of higher education and encompasses all learning in broad areas through their solid knowledge in basic sciences and specific for engineering;
- Civic learning: enables students to respond to social, environmental, and economic challenges at local, national, and global levels [11].

8. DISCUSSIONS AND CONCLUSIONS

More than ever, it is necessary to form professionals equipped with tools that enable them to respond quickly to the changing work market and the unpredictable new professional expertise fostered by Scientific and Technological development. In fact, both, basic and applied engineering research, will be critical to the design and development of processes and systems on which every major sector of the country's economy depends. Both forms of research will be essential to meet the challenges and taking advantage of the opportunities that lay ahead.

While engineers are expected to be well grounded in the fundamentals of science and mathematics, they are also increasingly expected to acquire skills in communication, teamwork, adaptation to change, and social and environmental consciousness. The qualities most highly valued in graduates, beyond technical knowledge or skills, are: The ability to communicate well; a commitment to lifelong learning; the ability to adapt to an increasingly diverse world; the ability, not only to adapt to change, but to actually drive change. For this reason, a classic approach seems more useful for the demands of today's job market. It is at least interesting that the classic approach is being neglected, at a time when its product might be more interesting.

Currently, there are no surveys to determine if this group of students is better trained and/or has better skills, however it is estimated that during the internship period, they show better knowledge of mathematics, which seems to enhance their performance. This is the conclusion taken from the survey applied, every three months, to institutions which received students as interns, in which they grade students' performance during the internship. By better performance it means that students can cope better with the challenges and difficulties of problem solving and have a better understanding of the importance to search for the best solutions.

So far, the design and implementation of this program has been very positive. The first group of students, who will graduate in 2018, the students who are in internship at the 4th year have showed better performance, comparing to the other program, which is a first step to success. It means that the students have better grades, especially in the second and third years of the program so far. The Pre – Program, in special, has a good effect on students, since it provides them some elements that they can use such as Psychology and technical English.

The internship period, recommended in the 4th year of the program, has just started and the engineering college has been working to help students to find good training placements. It is crucial to advise them and to ensure proper conditions, in accordance with the law, in order to avoid waste of time and possible misuse of qualified labour.

This program, which is knowledge cantered, is responding very well in terms of students' enrolment and it is necessary to develop a survey to find out what are the elements that make students opt for this kind of education: the different approach, the strong knowledge basis or the possibilities of performing in any field of civil engineering, since the present job market is mutant and challenging. This shall be the next step for 2017, to develop a survey, which will allow us to refine the program and provide an input about the most relevant aspects of the program. Results shall be known at the beginning of 2018.

9. ACKNOWLEDGMENT

This work is financed by FEDER funds through the Competitivity Factors Operational Programme – COMPETE: POCI-01-0145-FEDER-007043 and by national funds through FCT – Foundation for Science and Technology within the scope of the project POCI-01-0145-FEDER-007136 and project UID/CEC/00319/2013.

REFERENCES

[1] M. S. Knowles, E. F. Holton III, and R. A. Swanson, *The adult learner: The definitive classic in adult education and human resource development*. Routledge, 2014.

[2] M. J. de Vries, L. Gumaelius, and I.-B. Skogh, “Pre-university engineering education,” in *Pre-university Engineering Education*, Springer, 2016, pp. 13–25.

[3] S. Amat, S. Busquier, M. Jose Legaz, and J. Ruiz, “Unifying the classical approach with new technologies: An innovative proposal for teaching mathematics in engineering,” *Int. J. Interact. Multimed. Artif. Intell.*, vol. 3, no. 4, SI, pp. 17–19, 2015.

[4] P. G. Altbach, “What Higher Education Does Right: A Millennium Accounting,” *Chang. Mag. High. Learn.*, vol. 32, no. 4, pp. 52–52, 2015.

[5] P. C. Wankat and F. S. Oreovicz, *Teaching Engineering*. Purdue University Press, 2015.

[6] E. Pâmîntaş, “Higher Technical Education - Research vs. Education. Technique Of Teaching, Between Classical And Modern,” *ACTA Univ. Cibiniensis*, vol. 66, no. 1, 2015.

[7] https://www.edfenergy.com/sites/default/files/jobs-of-the-future.pdf

[8]C. da R. Brito, M. M. Ciampi, R. M. Vasconcelos, L. A. M. Amaral, and V. F. A. Barros, “Engineering Adventure for Youth Generations,” in *2016 ASEE Annual Conference & Exposition Proceedings*, 2016.

[9] C. da R. Brito, M. M. Ciampi, V. F. A. Barros, L. A. M. Amaral, and R. Vasconcelos, “Engineering the engineering program: The year of discovery,” in *2016 IEEE Frontiers in Education Conference (FIE)*, 2016, pp. 1–4.

[10] C. da R. Brito, M. M. Ciampi, L. A. M. Amaral, R. Vasconcelos, and V. F. A. Barros, “The Year of Discovery,” in *44th SEFI Annual Conference*, 2016.

[11] C. da R. Brito, M. M. Ciampi, L. A. M. Amaral, R. Vasconcelos, and V. F. A. Barros, “Creating New Learning Environment to Foster Enrollment in Engineering Programs,” in *Interactive Collaborative Learning: Proceedings of the 19th ICL Conference - Volume 1*, M. E. Auer, D. Guralnick, and J. Uhomoibhi, Eds. Cham: Springer International Publishing, 2017, pp. 455–463.